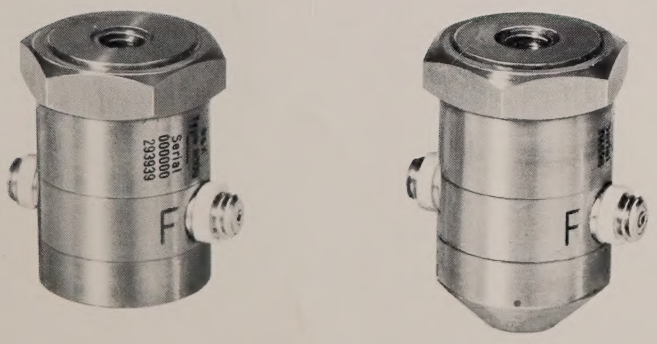
8000
8001

Instruction Manual

Impedance Heads Type 8000 and 8001



The Impedance Heads 8000 and 8001 are complete transducers for mechanical impedance measurements or any other measurements where it is desirable to have acceleration and force signals simultaneously at the same point. The 8000 is for medical use and the 8001 is a general purpose unit.

Brüel & Kjær

2-033 0500-2A

IMPEDANCE HEADS
TYPE 8000 AND 8001

Revision September 1982

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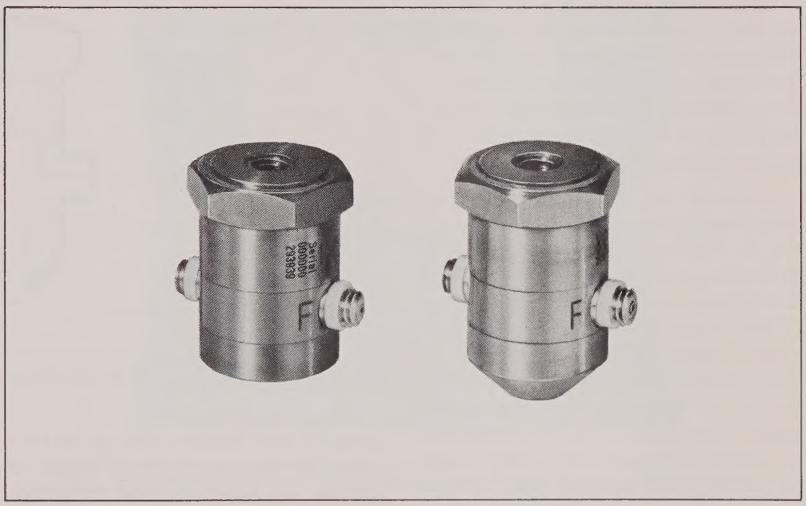
types 8000 and 8001

Impedance Heads

FEATURES:

- Integrated piezoelectric accelerometer and force gauge mounted very close to the driving point
- Frequency range up to 10 kHz with ± 1° accuracy of impedance phase angle
- Working temperature up to 260°C
- High stiffness below force gauge
- Low mass driving platform
- Titanium housing
- Individual calibration chart supplied
- Temperature stabilized force gauge and accelerometer sensitivities



The Impedance Heads Types 8000 and 8001 and the Mini-Shaker Type 4810 offer a complete transducer-driver combination for mechanical impedance measurements. The two impedance heads are of the same construction and differ mainly in the method of contacting the test specimen. The 8001 is a general purpose Impedance Head for mechanical impedance measurements on light structures whereas the 8000 is designed for calibration of the Artificial Mastoid Type 4930 and for mechanical impedance measurements on soft materials. In the medical field the 8000 can be used for the measurement of mechanical impedance on the human body.

The construction of the Impedance Heads can be seen in Fig.2. They consist of an accelerometer and a force gauge built together in a common titanium housing. An important feature of this construction is that the force gauge is located very close to the driving point giving a stiff, low mass coupling to the test point.

A very extensive calibration and temperature stabilizing procedure has been undertaken in order to ensure completely predictable performance and stable operation both in the laboratory and under field conditions. Each Impedance Head undergoes an individual calibration check. Figs.1 and 4 give examples of the calibration chart supplied.

USES:

- Mechanical impedance measurement and analysis of the dynamic behaviour of light structures, such as:
  Light airframes and panels
  Models of structures
  Light machinery parts
  Rotor blades of small turbines and air ventilators
  Structures of polymers, rubbers and fibres
- Calibration of Artificial Mastoids
- Biological measurements

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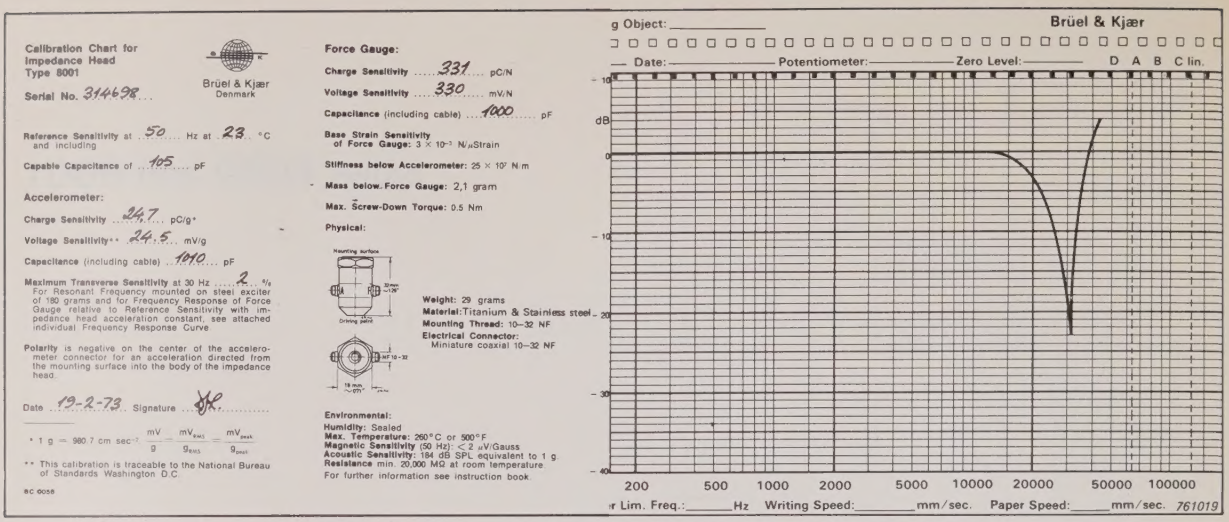

Calibration Chart for Impedance Head Type 8001
Brüel & Kjær Denmark
Serial No. 314698
Reference Sensitivity at 50 Hz at 23 °C and including
Capable Capacitance of 105 pF
Accelerometer:
Charge Sensitivity 24.7 pC/g*
Voltage Sensitivity** 24.5 mV/g
Capacitance (including cable) 1010 pF
Maximum Transverse Sensitivity at 30 Hz 2 %
For Resonant Frequency mounted on steel exciter of 180 grams and for Frequency Response of Force Gauge relative to Reference Sensitivity with impedance head acceleration constant, see attached individual Frequency Response Curve
Polarity is negative on the center of the accelerometer connector for an acceleration directed from the mounting surface into the body of the impedance head.
Date 19-2-73 Signature
* 1 g = 980.7 cm sec⁻²
** This calibration is traceable to the National Bureau of Standards Washington D.C.
ac dose
Force Gauge:
Charge Sensitivity 331 pC/N
Voltage Sensitivity 330 mV/N
Capacitance (including cable) 1000 pF
Base Strain Sensitivity of Force Gauge: 3 × 10⁻³ N/μStrain
Stiffness below Accelerometer: 25 × 10⁷ N/m
Mass below Force Gauge: 2,1 gram
Max. Screw-Down Torque: 0.5 Nm
Physical:
Weight: 29 grams
Material: Titanium & Stainless steel
Mounting Thread: 10–32 NF
Electrical Connector: Miniature coaxial 10–32 NF
Environmental:
Humidity: Sealed
Max. Temperature: 260°C or 500°F
Magnetic Sensitivity (50 Hz): < 2 μV/Gauss
Acoustic Sensitivity: 184 dB SPL equivalent to 1 g
Resistance min. 20,000 MΩ at room temperature
For further information see instruction book.
g Object:
Brüel & Kjær
Date: Potentiometer: Zero Level: D A B C lin.
dB
200 500 1000 2000 5000 10000 20000 50000 100000
Lim. Freq.: Hz Writing Speed: mm/sec. Paper Speed: mm/sec.
761019

Fig.1. Typical calibration chart as supplied with each Impedance Head Type 8001

Mechanical Impedance

Mechanical impedance is defined as the ratio of the force exciting a structure to the resulting velocity. To make a complete recording of the modulus of impedance versus frequency the modulus of velocity is kept constant.

A set-up for the measurement of mechanical impedance is shown in Fig.3. The generator section of a Frequency Analyzer/Generator Type 2010 drives a Power Amplifier Type 2706, which in turn drives the small Vibration Exciter Type 4810. This applies a vibratory force to the structure through the impedance head Type 8001. As the excitation frequency is swept over the range of interest, the velocity level is kept constant by integrating the accelerometer output in Preamplifier Type 2635 and using the velocity signal to control the compressor of the generator.

The output signal from the force gauge is now proportional to the mechanical impedance. This signal is fed via the Accelerometer Preamplifier Type 2634 to the Measuring Amplifier Section of the 2010 and from there to the Level Recorder Type 2307 which is synchronised with the frequency sweep of the generator. The mechanical impedance versus frequency is recorded on preprinted frequency calibrated paper.

When a phase meter (e.g. Type 2971) or an oscilloscope is introduced into the set-up, the phase angle can be measured. The modu-

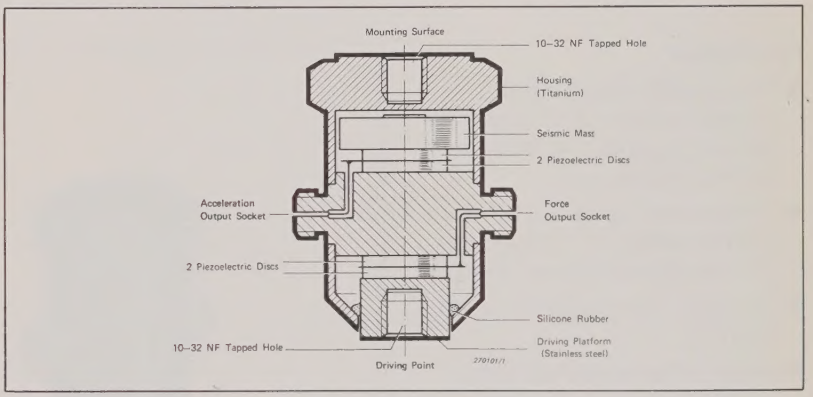


Fig.2. Schematic drawing of Type 8001

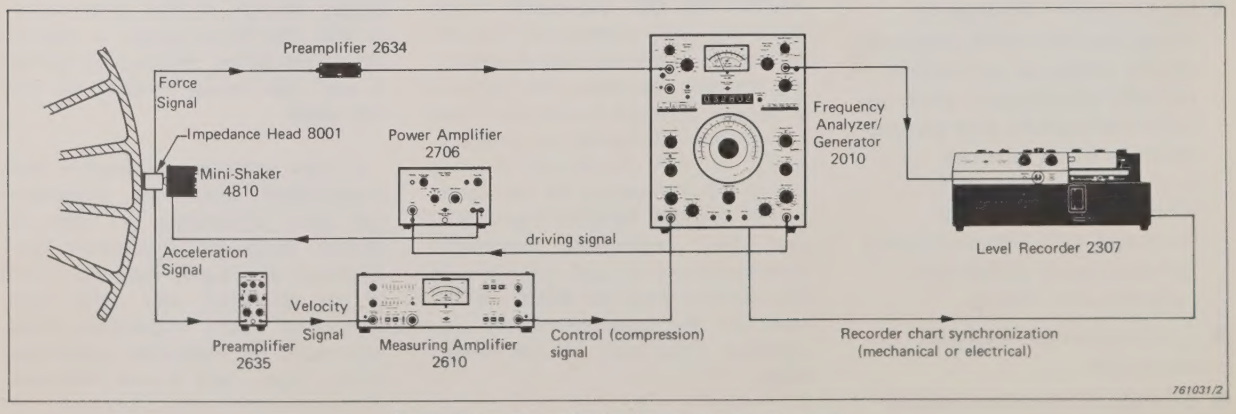


Fig.3. Set-up for mechanical impedance measurement

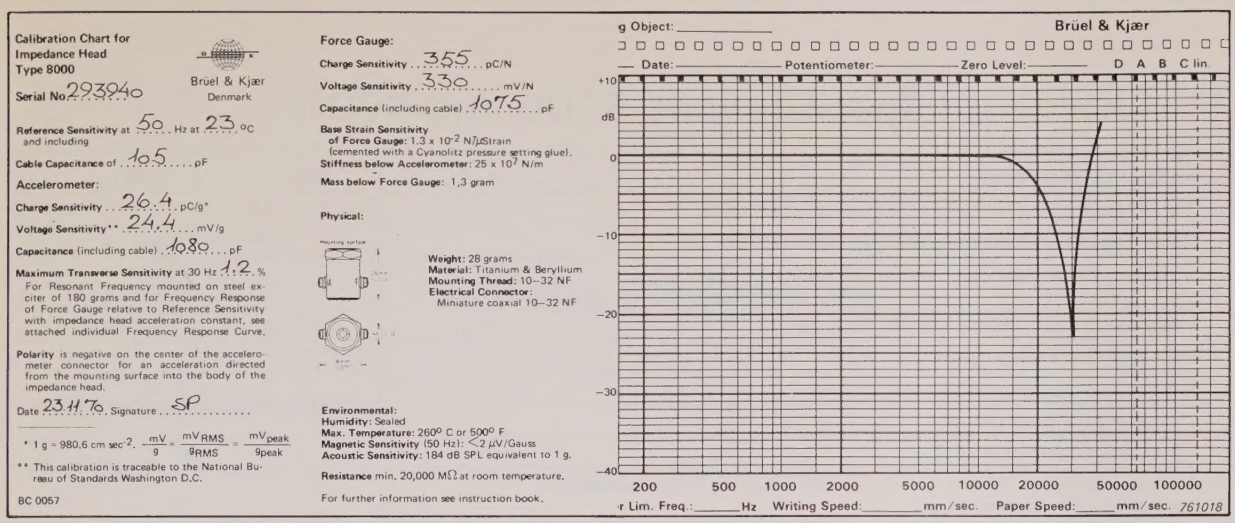

Calibration Chart for
Impedance Head
Type 8000
Serial No. 29394o
Brüel & Kjær
Denmark
Reference Sensitivity at 50 Hz at 23 °C and including
Cable Capacitance of 105 pF
Accelerometer:
Charge Sensitivity 26.4 pC/g*
Voltage Sensitivity** 24.4 mV/g
Capacitance (including cable) 1080 pF
Maximum Transverse Sensitivity at 30 Hz 1.2 %
For Resonant Frequency mounted on steel exciter of 180 grams and for Frequency Response of Force Gauge relative to Reference Sensitivity with impedance head acceleration constant, see attached individual Frequency Response Curve.
Polarity is negative on the center of the accelerometer connector for an acceleration directed from the mounting surface into the body of the impedance head.
Date 23.11.76 Signature SP
* 1 g = 980,6 cm sec-2. mV/g = mVRMS/gRMS = mVpeak/gpeak
** This calibration is traceable to the National Bureau of Standards Washington D.C.
BC 0057
Force Gauge:
Charge Sensitivity 355 pC/N
Voltage Sensitivity 330 mV/N
Capacitance (including cable) 1075 pF
Base Strain Sensitivity of Force Gauge: 1.3 x 10-2 N/μStrain (cemented with a Cyanolitz pressure setting glue).
Stiffness below Accelerometer: 25 x 10^7 N/m
Mass below Force Gauge: 1,3 gram
Physical:
Weight: 28 grams
Material: Titanium & Beryllium
Mounting Thread: 10–32 NF
Electrical Connector: Miniature coaxial 10–32 NF
Environmental:
Humidity: Sealed
Max. Temperature: 260° C or 500° F
Magnetic Sensitivity (50 Hz): <2 μV/Gauss
Acoustic Sensitivity: 184 dB SPL equivalent to 1 g.
Resistance min. 20,000 MΩ at room temperature.
For further information see instruction book.
g Object:
Brüel & Kjær
Date: Potentiometer: Zero Level: D A B C lin.
+10 dB 0 −10 −20 −30 −40
200 500 1000 2000 5000 10000 20000 50000 100000
r Lim. Freq.: Hz Writing Speed: mm/sec. Paper Speed: mm/sec.
761018

Fig.4. Typical calibration chart as supplied with each Impedance Head Type 8000

lus and phase angle can then be converted into the resistive and reactive components of mechanical impedance.

Mass Compensation

Measurements on specimens whose effective dynamic mass is of the same order as the mass below the force gauge of the Impedance Head, will require electrical compensation. For this purpose the Mass Compensation Unit Type 5565 is available on special order.

Impedance Head Type 8001

Is intended for impedance measurements on light structures which have a dynamic mass of less than 1,5 kg (for 10% max. error). The driving platform has the small surface area necessary for making point impedance measurements on more flexible objects such as thin shells, panels etc. Attachment of the driving platform to the measuring object is made through a specially weakened stud, supplied as a standard accessory, to limit possible excess torque loading on the driving platform. Additional weakened studs can be ordered under part number YS 0514.

Measurements on Heavier Constructions

For impedance measurements on heavier, stiff constructions where the applied force might exceed the force rating of the 8001, use a Type 8200 Force Transducer and a separate Piezoelectric Accelerometer, details of which are given in the B & K Short Form Catalogue.

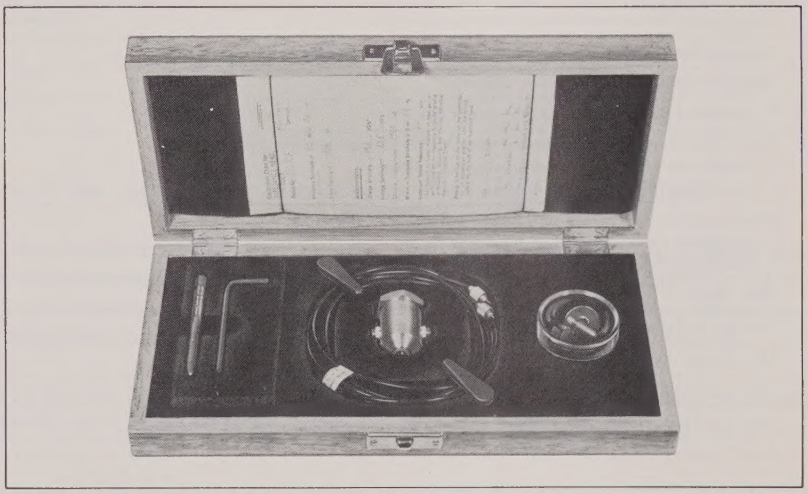


Fig.5. Mahogany case containing Impedance Head, accessories and calibration chart

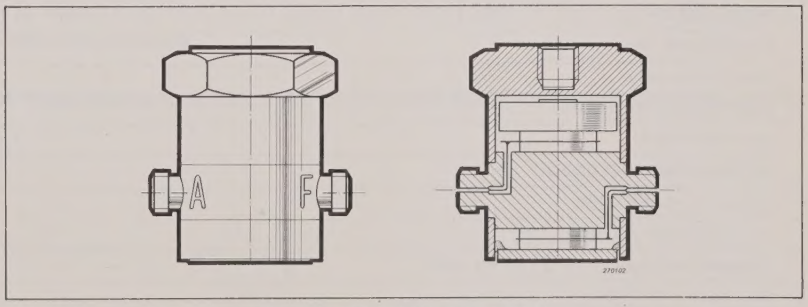


Fig.6. Impedance Head Type 8000

Impedance Head Type 8000

The driving platform here is a plane 1,75 cm² beryllium disc giving a standardized contact area to an artificial or human mastoid (BS 4009: 1966 and ISO R513). The plane platform is also very well suited for reproduceable measurements on soft materials.

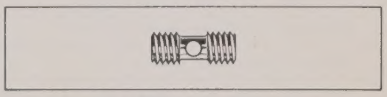


Fig.7. The weakened brass stud YS 0514 used to couple the driving point of Type 8001 to the test object in order to protect the driving platform against excess torque

Specifications 8000 and 8001

IMPEDANCE HEAD TYPE		8000	8001
*Typical Accelerometer Sensitivity, individually calibrated within 2%		3 pC/ms^{-2}, 3 mV/ms^{-2} (30 pC/g, 30 mV/g)	
*Typical Force Gauge Sensitivity, individually calibrated within 2%		370 pC/N, (370 mV/N)	
* Frequency Range (Hz)	± 5% ± 10%	1 — 6000 1 — 10000	
Diameter of surface contacting specimen (mm), (in)		15 (0,59)	8 (0,32)
Mass below Force Gauge (gram)		1,3	2,1
Stiffness below Accelerometer (N/m)		25×10^7	
* Accelerometer Capacitance (pF)**		1000	
* Force Gauge Capacitance (pF)**		900	
Accuracy of Impedance Phase Angle over specified Frequency Range (dependent on preamplifier in low frequency range)		± 1%	
Max. measurable Impedance, with accuracy better than 10% is limited by	Test object dynamic mass Test object contact stiffness	1,5 kg $2,5 \times 10^7$ N/m	
Force Gauge and Accelerometer Electrical connection		One side connected to base	
Acoustic Sensitivity of Accelerometer (dB SPL equivalent to 10 ms^{-2})		184	
Magnetic Sensitivity of Accelerometer mV/T		< 20	
* Transverse Sensitivity of Accelerometer (%)		< 3	
Base Strain Sensitivity of Accelerometer (m/s^2/μstrain) (g/μstrain) Impedance Head mounted on mounting surface Impedance Head mounted on driving point		 $< 5 \times 10^{-4}$ $< 5 \times 10^{-4}$	 (5×10^{-5}) (5×10^{-5})
Base Strain Sensitivity of Force Gauge (N/μstrain) Impedance Head mounted on mounting surface Impedance Head mounted on driving point		 $< 2 \times 10^{-5}$ $< 2 \times 10^{-2}$	 $< 2 \times 10^{-5}$ $< 3 \times 10^{-3}$
Max. Ambient Temperature (°C), (°F)		260 (500)	
Leakage Resistance (MΩ)		20000	
Max. Shock, typical (m/s^2) (g)		20000 (2000)	
Max. Load in Tension (static + dynamic) (N)		300	
Max. Load in Compression (static + dynamic) (N)		2000	
Max. Screw-down Torque (Nm)	of Mounting Surface of Driving Point	2,0 0,5	
Dynamic Linearity of Force Gauge for 50 N Peak (%)		± 2	
Sealing		Silicone rubber	
Height (mm), (in)		28,5 (1,12)	32 (1,26)
Weight (gram), (oz)		29 (1,02)	
Material of housing		Titanium	
Material below Force Gauge		Beryllium	St. steel
Mounting Thread		10 — 32 NF	
ACCESSORIES INCLUDED			
Mahogany case KE 0066		1	
Low-noise Cable AO 0038		2	
Threaded steel studs, 10 — 32 NF YQ 2962		4	
Mica washer YO 0534		3	
Electrically isolated stud, 10 — 32 NF YP 0150		2	
Nut, 10 — 32 NF YM 0414		1	
Screw tap, 10 — 32 NF QA 0029		1	
Allen key, 3/32" for studs QA 0013		1	
Individual calibration chart		1	
Weakened stud, 10 — 32 NF YS 0514		0	5

* Individual values at room temperature given on the calibration chart

** Including standard low noise cable 1,2 m (4 ft) long

2. THEORETICAL CONSIDERATIONS

2.1. MECHANICAL IMPEDANCE

2.1.1. Definitions

Mechanical impedance can be defined as the resistance of an object to being set in motion. A dynamic force applied to an object will result in a certain velocity, in accordance with the equation:

$$\bar{Z} = \frac{\bar{F}}{\bar{V}} \qquad 2.1$$

where $\bar{F}$ is the force, $\bar{V}$ the velocity and $\bar{Z}$ the mechanical impedance vectors.

In the equation, the quantities are stated as vectors, as in the majority of cases there will be a phase difference between the applied force and the resulting velocity. On the other hand, it is not always necessary to consider this phase difference when making measurements. Often it is sufficient to measure the magnitudes of the resulting quantities.

From the definition it can be seen that a mechanical element with a high impedance will require a large force to set it in motion, and one with a low impedance will require but a small force.

Mechanical Impedance is distinguished by two forms (see Fig.2.1). When velocity and force are measured at the same point, this form is called Point Impedance. If, on the other hand, the response is measured at a point apart from the point of excitation the impedance is called Transfer Impedance.

The concept of **Point Impedance** describes the structure's ability to withstand or absorb a vibration.

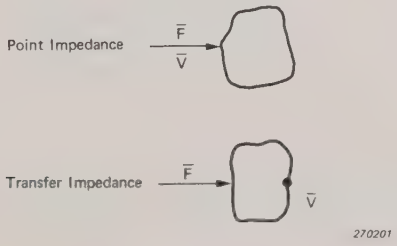


Fig.2.1. Difference between Point Impedance and Transfer Impedance

Transfer Impedance describes the structure's ability to transmit or isolate a vibration.

It is common among mechanical engineers to speak of the **mobility** of a structure. This is the reciprocal of its impedance.

Although mechanical impedance and mobility are the two most common quantities measured, it is, of course, possible to measure the acceleration or displacement relative to force as well. Thus, when the force is measured relative to the acceleration, one obtains the acceleration impedance, or **apparent mass**. Similarly, one can get the displacement impedance, or **dynamic stiffness**, and the acceleration mobility or **inertance**, and the displacement mobility, known as either the **compliance** or the **receptance**.

For a steady state system with sinusoidal excitation, the relationship between force, velocity and impedance can be demonstrated with a diagram such as that in Fig.2.2.

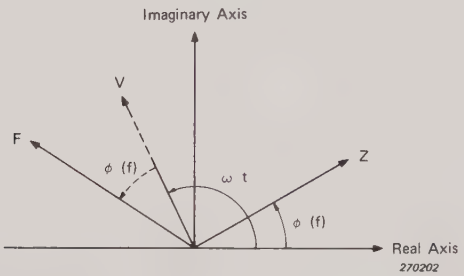


Fig.2.2. Relationships between force, velocity and impedance

The vectors $\bar{F}$ and $\bar{V}$ can be expressed by the equations

$$\bar{F} = F \exp j (\phi (f) + \omega t) \qquad 2.2$$

and

$$\bar{V} = V \exp j \omega t \qquad 2.3$$

where ϕ is the phase angle between F and V and ω the angular frequency.

Substituting these values into equation 2.1, one gets

$$\bar{Z} = \frac{\bar{F}}{\bar{V}} \exp j \phi (f) \qquad 2.4$$

The impedance vector has a certain phase angle ϕ for a given frequency, which is the difference in phase between the force and velocity vectors, regardless of time.

2.1.2. Mechanical Elements

In studying a mechanical system, it is often useful to break it down into a number of simple ideal elements, namely masses, stiffnesses and dampers. Each of these elements has its own impedance characteristics, as shown in Table 2.1.

This is also shown vectorially in Fig.2.3.

Type	Symbol	Impedance Vector Value	Numerical Value	Phase angle
Mass		j ω m	ω m	90°
Stiffness		–j k/ω	k/ω	–90°
Damper		c	c	0°

780186

Table 2.1. Impedance characteristics of mechanical elements

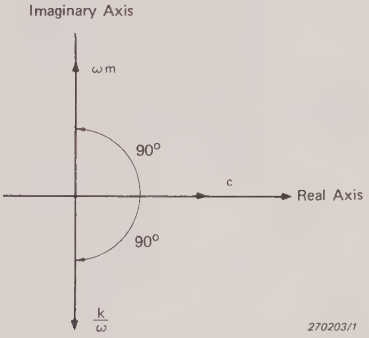


Fig.2.3. Phase relationship of mass, stiffness and damping

If impedance is plotted against frequency, as in Fig.2.4, it can be seen that a pure spring will be represented by a downward sloping line and a pure mass by an upward sloping line. The lines would have a 1:1 slope on a log-log scale, which on the dB scale used in Fig.2.4 corresponds to –6 dB and + 6 dB per octave respectively. The damping vs. frequency plot is represented by a horizontal line.

Mechanical systems generally have much more complicated mechanical impedance curves than this, of course, but one can still find the influence of the basic elements in their curves.

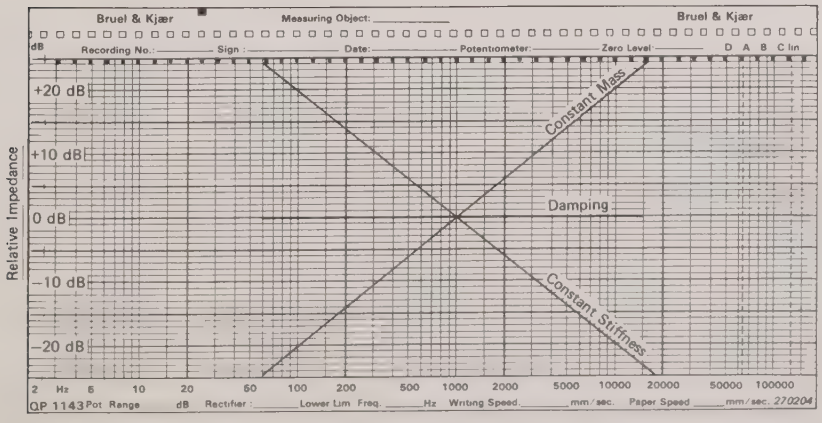


Fig.2.4. Impedance vs. frequency for mass, stiffness and damping

2.2. MASS COMPENSATION

2.2.1. Why Mass Compensation is Necessary

Fig.2.5 is a vectorial representation of the action of the Impedance Head. (Compare with Fig.2.2). The relation betwen $\bar{F}_o$, the force delivered to the object; $\bar{V}$, its velocity; and $\bar{Z}_o$, its mechanical impedance, has already been covered. However, there is one other factor which should be considered before attempting mechanical impedance measurements.

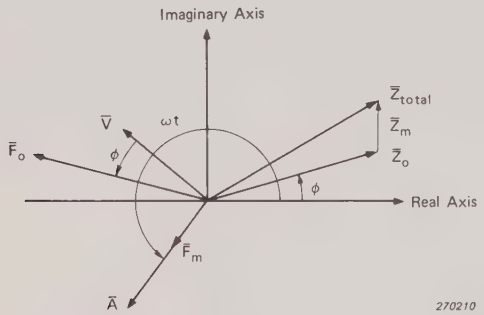


Fig.2.5. Vectorial representation of the action of an Impedance Head

As seen in Figs.2 and 6, Chapter 1, the mass of the driving platform is located beneath the piezoelectric discs and therefore contributes an additional impedance. This can be considered a pure mass with its force vector $\bar{F}_m$ in phase with the acceleration $\bar{A}$ of the Impedance Head. Looked at from a mechanical impedance standpoint, this mass adds an impedance vector $\bar{Z}_m$ onto the impedance of the object $\bar{Z}_o$, producing a resultant vector $\bar{Z}_{total}$.

When Z_o is greater than 10 times Z_m, the error produced in Z_{total} will be less than 1 dB. If the two are of the same magnitude, as for example when the Impedance Head Type 8000 is used to calibrate the Artificial Mastoid, it is necessary to compensate for this mass.

2.2.2. Electrical Compensation

The output signal, E_{Fm}, due to the mass below force gauge is:

$$E_{Fm} = m \times A \times S_F$$

where S_F is the force gauge.

This can also be written:

$$E_{Fm} = m \times |\bar{U}_A| \times \frac{E_A}{S_A} \times S_F$$

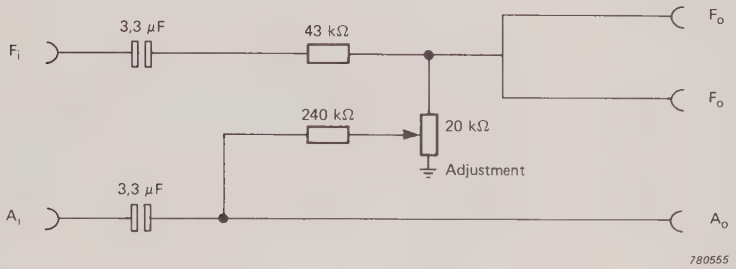
where U_A is a unit acceleration vector, S_A is the sensitivity of the accelerometer, and E_A is the output signal of the accelerometer.

The Impedance Head is constructed in such a way the two signals E_A and E_{Fm} are 180° apart. Therefore a compensation voltage, E_c, can be obtained by voltage division. This

voltage, when added to E_{Fm}, results in a cancellation of the force signal and therefore the mechanical impedance measured will be the true mechanical impedance of the object measured.

The Brüel & Kjær Mass Compensation Unit Type 5565 is such an instrument. Fig.2.6.a shows a picture of the Mass Compensation Unit and Fig.2.6.b shows its circuit. The force signal is attenuated 10 dB through the unit.

(a)



(b)

Fig.2.6. Mass Compensation Unit Type 5565 (a), with circuit diagram (b)

3. CHARACTERISTICS

3.1. CONSTRUCTION

Fig.2, Chapter 1 shows a cutaway view of the Type 8001. Into the titanium housing are built an accelerometer and a force gauge. These are made up of pairs of lead zirconate titanate piezoelectric discs with conductors sandwiched between them and leading out to output sockets in the housing. The discs are artificially aged for long-term stability. The outputs accept standard Brüel & Kjær mini coaxial cables and are threaded with a 10–32 UNF thread.

An inertial mass of tungsten alloy is mounted above the accelerometer discs. The driving platform below the force gauge is machined from beryllium for high stiffness and low mass. It weighs 1,0 gram. At both the mounting and the driving end there is a 10–32 UNF threaded hole. The driving end is sealed with silicone rubber so that the Impedance Head can be used at any humidity.

The Type 8000 (Fig.6, Chapter 1) is constructed exactly the same as the Type 8001 except for the driving platform. This is designed to meet the BS 4009: 1966 and ISO R 512 standards for contact areas for artificial or human mastoids. It has a contact area of 1,75 cm^2 and weighs 1,1 grams.

3.2. FACTORY CALIBRATION

Each individual Impedance Head is calibrated before it leaves the factory and a calibration chart is included with the instrument (see Figs.1 and 4, Chapter 1). Since the piezoelectric discs are artificially aged during manufacture, they are extremely stable, and under normal use the instrument should not need to be re-calibrated. However, if the instrument were subjected to intense heat or shock it would be be advisable to re-calibrate.

3.2.1. Sensitivity

The sensitivity of the Impedance Head is stated at 50 Hz at 23° C. Both the Accelerometer Sensitivity and the Force Gauge Sensitivity are measured with a set-up as shown in Fig.3.1.

The Accelerometer Sensitivity is measured without the load and the output of the Impedance Head is compared with the Standard Accelerometer. The Sensitivity is stated with an accuracy of 2%.

The Force Gauge Sensitivity is measured with masses of 20,4 and 10,2 grams attached and with no mass. A vibration level of 98 m/s^2 is used, and the output signals therefore correspond to 2 N, 1 N and 0 N respectively. Thus two sensitivities are obtained by

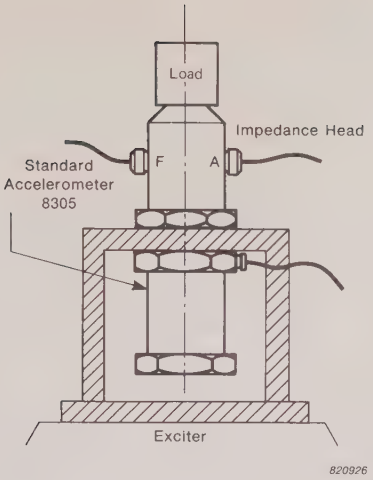


Fig.3.1. Arrangement used for calibration of Impedance Heads

subtracting the results: output (2 N) – output (1 N) = output (1 N) and output (1 N) – output (0 N) = output (1 N). The maximum allowable difference is 2%, ensuring good linearity of the transducer.

3.2.2. Frequency Response

The curve supplied with the calibration chart is the output of the unloaded force gauge when the impedance head is excited to give a constant voltage output from the accelerometer throughout the frequency range. The resonance of the accelerometer appears as a valley in the force gauge output (since less driving force is required to give the required voltage output at the frequency of resonance). The accelerometer resonance occurs at a frequency of about 40 kHz, while the force gauge resonance is at about 80 kHz.

As can be seen from Figs.1 and 4, Chapter 1, the response of the impedance head is flat up to 15 kHz, which is sufficient for most mechanical impedance measurements.

3.3. CALIBRATION BY USER

If it is desired to re-calibrate the Impedance Head it can be easily done using a Brüel & Kjær Accelerometer Calibrator Type 4291. This is a portable vibration exciter which has a built-in load indicator and can be best used to calibrate transducers at 10,0 ms^{-2} peak at 80 Hz.

3.3.1. Accelerometer

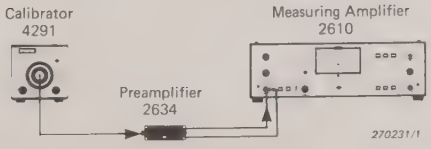


Fig.3.2. Simple instrument setup for calibration of accelerometers

Fig.3.2 shows the arrangement for calibration of accelerometers. The procedure is as follows:

1. Calibrate the Measuring Amplifier for "Preamp. Input" using its 50 mV RMS reference voltage.

2. Switch the 4291 to "Internal Generator". The calibrator will now vibrate the specimen at 79,6 Hz at 10 ms^{-2} peak.

3. Adjust the ACC. LEVEL control until the 4291 METER deflection is equal to the mass attached to the 4291 vibration table.

4. Read off the voltage output indicated on the Measuring Amlifier.

If the Measuring Amplifier is set to read RMS, then the accelerometer sensitivity (in mV per ms^{-2}) is equal to the reading (in mV) divided by 7,07 times the total gain of the Preamplifier and Measuring Amplifier; if PEAK, then 10,0 times.

3.3.2. Force Gauge

The same arrangement can be used to calibrate the force gauge, with the difference that two known weights are added to the Impedance Head. A procedure similar to that described in 3.2.1 is used. With the vibration level of 10 ms^{-2} obtained by the calibrator masses of 10,0 and 20,0 grams will give force differences of 0,1 N. The difference in peak mV need therefore only be multiplied by 10 to obtain the sensitivity in mV/N.

Note: Remember to re-adjust the indicated level on the Calibrator METER for the additional weight.

With the Type 8001 Impedance Head the weights can be screwed directly on and the accuracy of this calibration is better than 2%. However, with the Type 8000 the weight must be fixed with wax or double-sided adhesive tape. The 4291 may be operated on its four detachable legs screwed into its rear panel, thereby reducing the peak stress on this fixing.

3.4. TEMPERATURE SENSITIVITY

Both the force gauge and the accelerometer are sensitive to large changes in temperature. If the Impedance Head is to be used at elevated temperatures it is necessary to apply the appropriate corrections. Fig.3.4 shows variations in capacitance, charge sensitivity and voltage sensitivity for the range 25 to 250°C. The error is given as dB, based upon reference values, and applies to both the accelerometer and the force gauge.

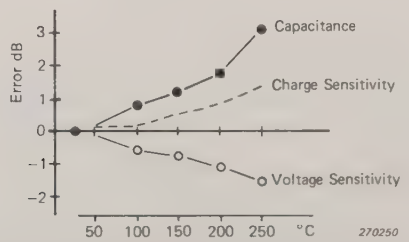


Fig.3.3. Temperature sensitivity curves for the Impedance Heads 8000 and 8001

4. PRACTICAL CONSIDERATIONS

4.1. FIXING THE IMPEDANCE HEADS TO MEASURING OBJECTS

As with accelerometers, the method of fixing the Impedance Head to an object can affect the results. The Type 8000 is, of course, primarily designed to rest upon soft surfaces such as rubber or skin. It can, however, be fixed to smooth, flat surfaces such as steel plate, but it must be attached by means of double-stick tape, a thin layer of wax, or similar fixatives. The choice of methods will depend upon the frequency and magnitude of loading. The Type 8001 is designed to be screwed on to measuring objects, and when it is used in a vertical position, either upright or upside down, with symmetrical loading, no special precautions are necessary as long as the maximum tensile load of 300 N and the screw-down torque of 0,5 Nm (0,051 kg m, 4,42 lb in) are not exceeded.

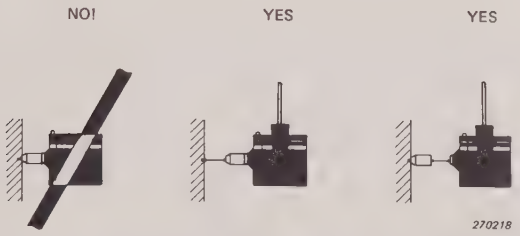


Fig.4.1. Recommended method of supporting the Vibration Exciter for measurements at odd angles

When the Impedance Head is used in a horizontal position, though, or when an unsymmetrical load is applied, a torsional load is placed on the connection, which is transmitted to the piezoelectric load cell, with injurious effects. The recommended method is to support the Vibration Exciter and Impedance Head with some sort of hangers and provide a flexible connection somewhere between the Exciter and the object (see Fig.4.1). The stiffness of the connection must be taken into account in subsequent calculations. Such a connection is shown in Fig.4.2.

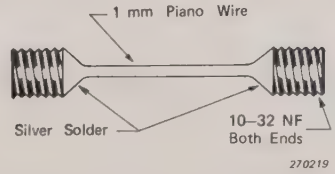


Fig.4.2. Flexible connection for use with Impedance Head Type 8001

4.2. LOADING

The maximum allowable loads in tension and compression are 300 N (30,6 kgf, 67,4 lbf.) and 2000 N (204 kgf, 448 lbf.). This is the total load, static plus dynamic, at which the piezoelectric crystals reach their elastic limit and sensitivity begins to fall off.

This should be taken into consideration before loading. The static load will, of course, be known beforehand and will be constant, and the dynamic load can be measured from the force gauge output.

Hence, if there is a total static tensile load of 200 N on the head it should not be driven over 100 N peak.

4.3. SELECTING A PREAMPLIFIER

Loading of a piezoelectric transducer's output even by relatively high impedance loads, can greatly reduce its sensitivity as well as severely limit its lower limiting frequency response. To prevent or help minimise these effects it is essential that the signal from a transducer is fed through a preamplifier before applying it to measuring and recording instrumentation.

There are two basic types of Preamplifier:

Voltage Preamplifiers. These are based on the use of a transducer as a voltage source. This requires that the preamplifier input impedance be high and non-capacitive so as not to load the output of the transducer. However, the capacitance of the cable connecting the transducer and preamplifier cannot be ignored as if not the exact capacitance value specified on the transducer calibration chart it will alter the voltage sensitivity of the transducer as well as change the lower limiting frequency for measurements.

Voltage preamplifiers are therefore recommended only with fixed relatively short transducer cables — preferably the individual cable supplied with the transducer employed. They are not suitable for use with long connection cables.

Charge Preamplifiers. These are based on the use of a transducer as a charge source and produce an output voltage proportional to the change in input charge. A large amount of capacitive feedback is used to obtain a very high preamplifier input capacitance and therefore very long transducer connection cables may be used without their shunt capacitance altering the charge sensitivity of the device or the lower limiting frequency for measurements. System calibration is thus considerably simplified as the charge sensitivity always remains that specified on the calibration chart.

Charge Preamplifiers are therefore preferred for use with the 8000 and 8001 especially where long or different lengths of cable are employed.

Brüel & Kjær make a range of Accelerometer Preamplifiers to suit virtually every application. All may be used with the Types 8000 and 8001, and all are of the Charge type except the 2650, which provides the options of charge or voltage input, as well as 4-digit sensitivity-conditioning.

For most applications the Type 2635 is suitable, as it is battery operated and has versatile signal-conditioning facilities, including integrators for velocity and displacement outputs.

The Type 2651 provides an extra-low frequency response (down to 0,003 Hz), and the integrator needed for velocity measurements, but has no sensitivity-conditioning. For further details consult the B & K Short Form Catalogue.

4.4. MEASURING IMPEDANCE

Mechanical impedance Z is defined by the relation

$$Z = \frac{F}{V}$$

where F is force component and V velocity component. The velocity component is the time-integral of the acceleration component. To obtain a plot of Z the accelerometer output of the Impedance Head is integrated (by a Type 2651 Charge Amplifier, which has a velocity output) and fed to the Compressor Input of the Sine Generator. The action of the compressor loop is to keep V constant, whence Z becomes proportional to F, which is available at the output of the 5565 Mass Compensation Unit in the arrangement shown in Fig.4.3.

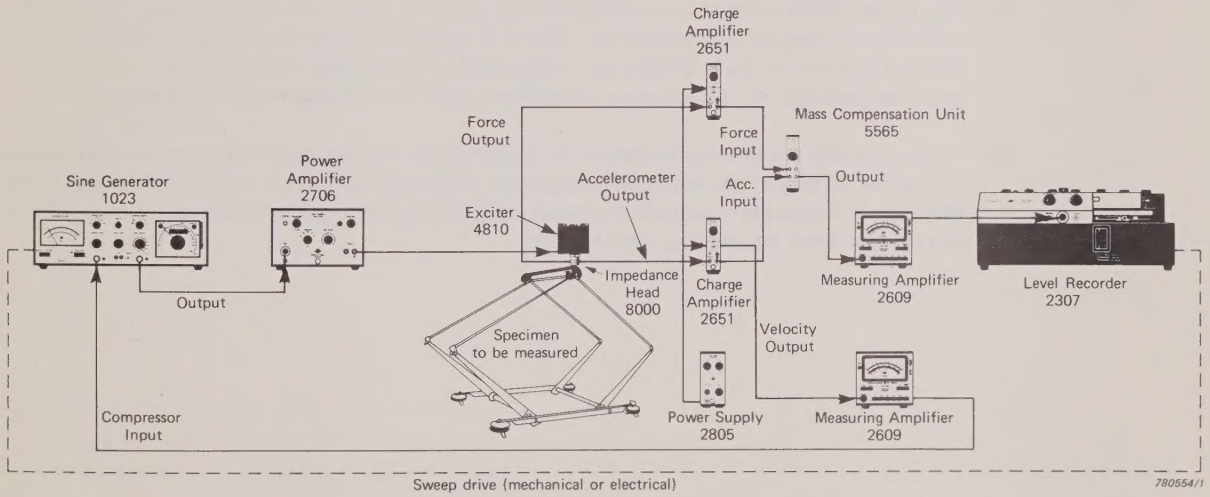


Fig.4.3. Arrangement of equipment for measuring and recording the mechanical impedance of a specimen

In this arrangement a second Measuring Amplifier is needed because the 2651 Charge Amplifier has insufficient output to drive a compressor loop directly. There is, of course, considerable scope for the user to vary the arrangement to make best use of the equipment available. For example, the 1023 Sine Generator may be replaced by a 1047 Exciter Control, which includes a vibration meter with integrator for use in its compressor loop, thus removing the need for the Measuring Amplifier in the compressor loop and the need for a Charge Amplifier having a velocity output.

To record the response of the mechanical impedance of the specimen, proceed as follows:

(1) Raise the Impedance Head clear of the specimen so that its driving platform does not contact anything.

(2) Adjust the output of the 1023 and the gain of the 2706 to obtain a vibration amplitude of about 10 ms^{-2} acceleration from the 4810 Exciter, at 1,0 kHz.

(3) Make the adjustments to the 2651 necessary to produce a reasonable dynamic range (refer to the Instruction Manual for the 2651 to do this).

(4) Set the ADJUSTMENT on the front panel of the 5565 Mass Compensation Unit to obtain the best null observable at the upper 2609 Measuring Amplifier.

(5) Restore the Impedance Head to contact with the specimen by the chosen method, following the recommendations made in Section 4.1.

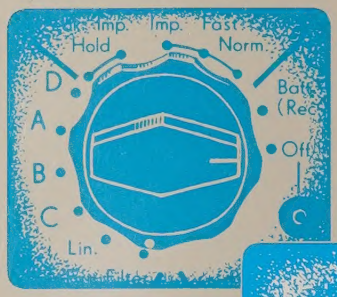
(6) Determine by reference to the Calibration Chart the setting required on the lower 2609 Measuring Amplifier to read conveniently a velocity level of about 1 mms^{-1} (or any other preferred level, taking account of rating limitations of the transducers), and select this setting.

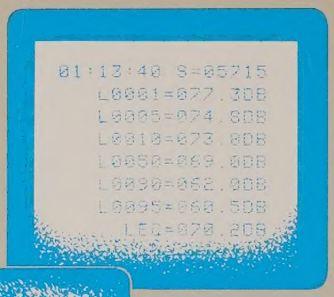
(7) Set up the Compressor on the 1023, as described in its Instruction Manual, so as to maintain constant the deflection observed on the lower 2609 Measuring Amplifier at the preferred velocity level.

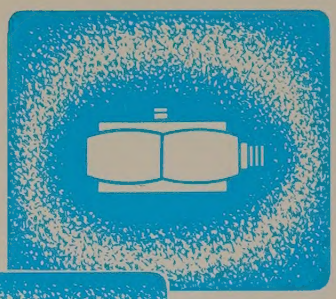
(8) The upper 2609 deflection is proportional to force, and the actual values of force and impedance may be calculated at 1,0 kHz if required by determining the constants of proportionality for both 2609's by reference to the Impedance Head Calibration Chart and the settings of the Charge Amplifiers and the Measuring Amplifiers.

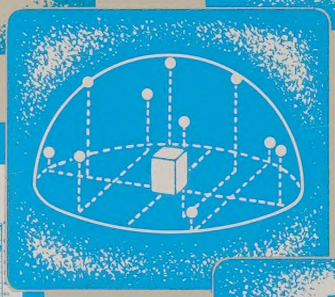
(9) To record the frequency variation of impedance, sweep the 1023 and the 2307 Level Recorder through the required frequency range as described in the 2307 Instruction Manual. If necessary, adjust the gain and change the potentiometer in the 2307 to obtain the best recording, and repeat.

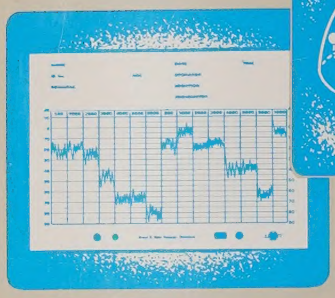
8000
8001

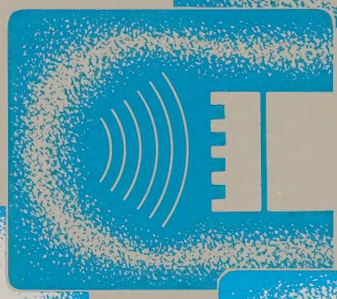


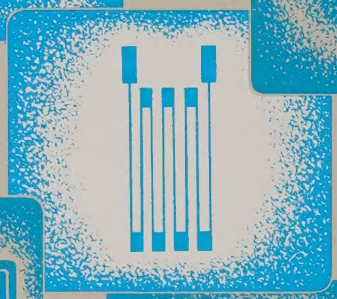


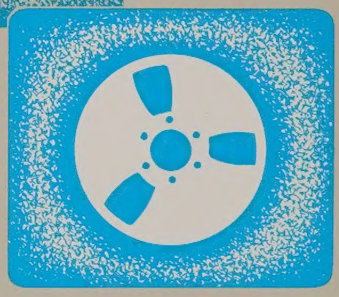


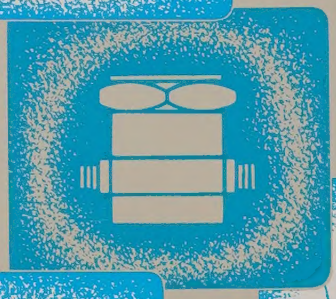


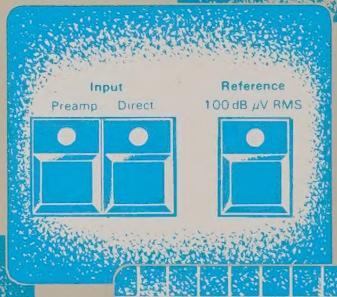


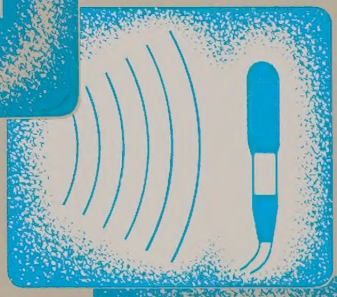


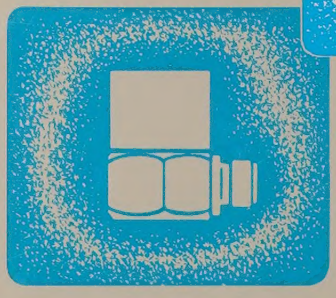


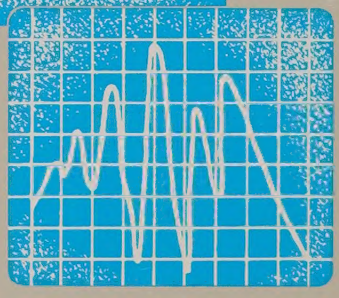


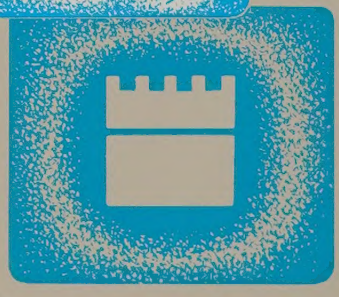












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